

**Space Weather Technical Forecast**

Issued on Monday 23 December 2024 at 13:20 Local

**This technical forecast provides a four-day assessment of space weather events. The probabilities stated below are for reaching or exceeding the given levels. For more information about space weather impacts please see the Met Office Space Weather Scales <https://www.metoffice.gov.uk/weather/learn-about/space-weather/uk-scales>**

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**Space Weather Forecast Headline: Further R1/R2 radio blackouts likely. Possible glancing CME early on 24 Dec with ongoing elevated solar winds.**

**Analysis of Space Weather Activity over past 24 hours**

**Solar Activity:** Solar activity has been Moderate with four M-class flares observed. The peak flare a M8.8 at 23/1115UTC from AR3932 in the southeast.

There are currently eleven sunspot regions on the visible disc, two of which are small and as yet unnumbered. The southeast quadrant remains the focus of solar activity, containing a cluster of the four largest regions, three of which (AR3928, AR3932 and AR3933) are moderately wide bipolar spot groups, showing some degree of magnetic complexity. AR3934 in the northeast is also appearing to be a fairly large spot group as it comes more into view. Other remaining regions are relatively small, stable and magnetically simple.

A CME associated with the recent M8.8 solar flare will be analysed for an Earth directed component as imagery becomes available. Otherwise a number of other CMEs have been observed in available imagery during the period, but analysis of these suggests none have an Earth directed component.

**Solar Wind / Geomagnetic Activity:** Solar winds, observed at L1 by DSCOVR and ACE have shown Elevated to Strong solar wind speeds, averaging around 550km/s, but reached a peak of 794km/s at 22/1817UTC. Density was average to below average. The Interplanetary Magnetic Field (IMF), Bt, was generally Weak, between 5-7nT. The north-south component, Bz, varied weakly throughout, ranging between +6 and -6nT. Geomagnetic activity was Quiet to Unsettled (Kp1-3).

**Energetic Particles / Solar Radiation:** High energy proton flux (greater than 10MeV) observed at GEO showed a very slow decline from a peak of around 5 pfu to start the period.

High energy electron flux (greater than 2MeV) observed by GOES16 peaked at Moderate levels, with 682pfu observed at 22/1735UTC. The associated 24-hour fluence was below the Active ( $1e8$  integrated flux) threshold. The 23/0001UTC observation was  $2.44e7$  integrated pfu, with a slight rising trend.

## Four-Day Space Weather Forecast Summary

**Solar Activity:** Occasional M-class flares are likely, with a slight chance of isolated X-class flares maintained throughout.

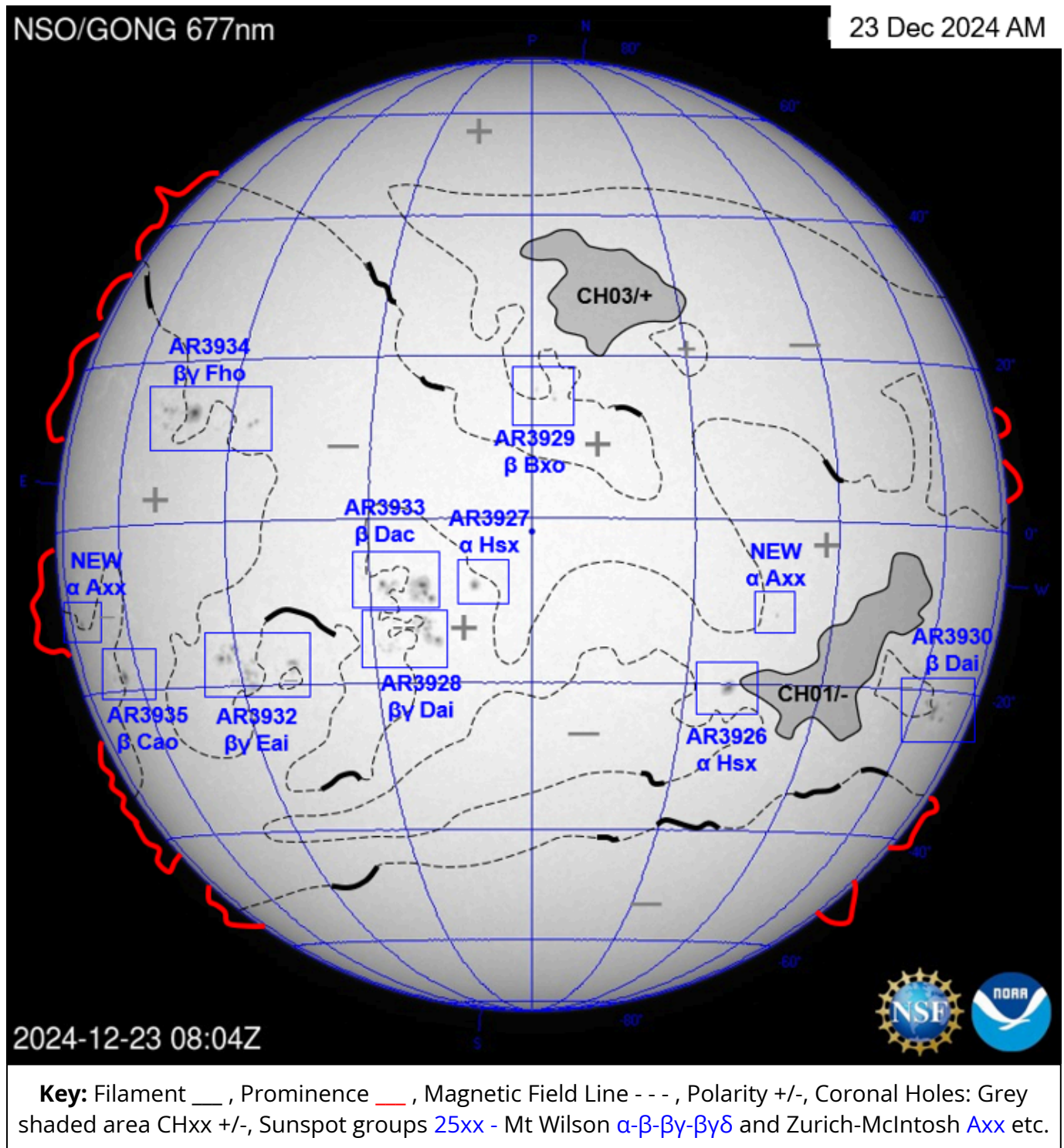
**Solar Wind / Geomagnetic Activity:** A filament lift-off from the northeast disk late in the UTC day 20 Dec was modeled and gives a potential peripheral glance around the turn of Day 2 (24 Dec). No other Earth-directed CMEs appear in the forecast, however the number of CMEs over the past few days means confidence is low.

Overall, conditions are likely to remain Quiet to Unsettled. Given current Elevated solar wind speeds, there is a chance of Active conditions through the period, tentatively peaking around Days 1 and 2 (23-24 Dec) due to CH01/- and possible glancing influence from the 20 Dec CME, with a slight chance of G1 Minor Geomagnetic Storms.

**Energetic Particles / Solar Radiation:** A persistent slight chance of S1-level or greater enhancements during the period, with current slightly enhanced near-Earth proton counts expected to ease, but balanced with the increasing threat of enhancement tied to the westward advance of the sunspot cluster located currently in the southeast.

The high energy electron forecast carries lower-than-average confidence due to inherited uncertainties from the geomagnetic forecast, especially surrounding any potential glancing CME influence around Day 2 (24 Dec). Overall, the chances of disturbances in the period are higher than average, with a gradually rising chance of the 24-hour fluence reaching Active levels.

Figure 1: Solar Synoptic Map Valid 23/0800 UTC.



## Geomagnetic Storms

A filament lift-off from the northeast from late in the UTC day on 20 Dec was modeled and gives a potential peripheral glance around the turn of Day 2 (24 Dec). There are also a number of other CMEs (coronal mass ejections) observed during the period, which have now been analysed, including two CMEs off the southwest limb early on 22 Dec, but current results suggest they are all directed off the Sun-Earth line.

Current solar winds are Elevated via an uncertain mechanism, most likely some connection to CH01/- given the negative phi angle. The coronal hole itself has shown changes in shape over the past three or four days, with some north-westward elongation perhaps taking place, making onset forecasting more complicated. Flux looping to its immediate west in GOES SUVI 195 imagery isn't helping by potentially masking any leading portion of this hole. Influence from this feature is expected to persist through Days 1-3 (23-25 Dec), likely gradually waning. Some further influence possible from CH03/+ in the northern hemisphere from Day 3 (25 Dec) onward, this features is also non-recurrence which further reduces confidence.

Overall, conditions are likely to remain Quiet to Unsettled. Given current Elevated solar wind speeds, there is a chance of Active conditions through the period, tentatively peaking around Days 1 and 2 (23-24 Dec) due to CH01/- and possible glancing influence from the 20 Dec CME, with a slight chance of G1 Minor Geomagnetic Storms. A mitigating factor against larger effects from any coronal hole is being near the semi-annual minimum coronal hole geo-effectivity near the solstice.

| Geomagnetic Storm           | Level    | Past 24 Hours<br>(Yes/No) | Day 1<br>(00-24 UTC) | Day 2<br>(00-24 UTC) | Day 3<br>(00-24 UTC) | Day 4<br>(00-24 UTC) |
|-----------------------------|----------|---------------------------|----------------------|----------------------|----------------------|----------------------|
| Probability<br>(Exceedance) |          |                           | (%)                  | (%)                  | (%)                  | (%)                  |
| Minor or Moderate           | G1 to G2 | No                        | 20                   | 20                   | 10                   | 10                   |
| Strong                      | G3       | No                        | 1                    | 5                    | 1                    | 1                    |
| Severe                      | G4       | No                        | 1                    | 1                    | 1                    | 1                    |
| Extreme                     | G5       | No                        | 1                    | 1                    | 1                    | 1                    |

## Geomagnetic Activity - Earthbound Coronal Mass Ejections

| Date/time<br>21.5R☉<br>(UTC) | Halo: Full<br>or<br>Partial | Source   | Source<br>Location | Estimated<br>Speed<br>(km/s) | Estimated<br>Arrival<br>Time (UTC) | Comments                               |
|------------------------------|-----------------------------|----------|--------------------|------------------------------|------------------------------------|----------------------------------------|
| 21/0535 UTC                  | Partial                     | Filament | NE quadrant        | 532                          | 24/0000 UTC                        | Possible<br>glance. Low<br>confidence. |

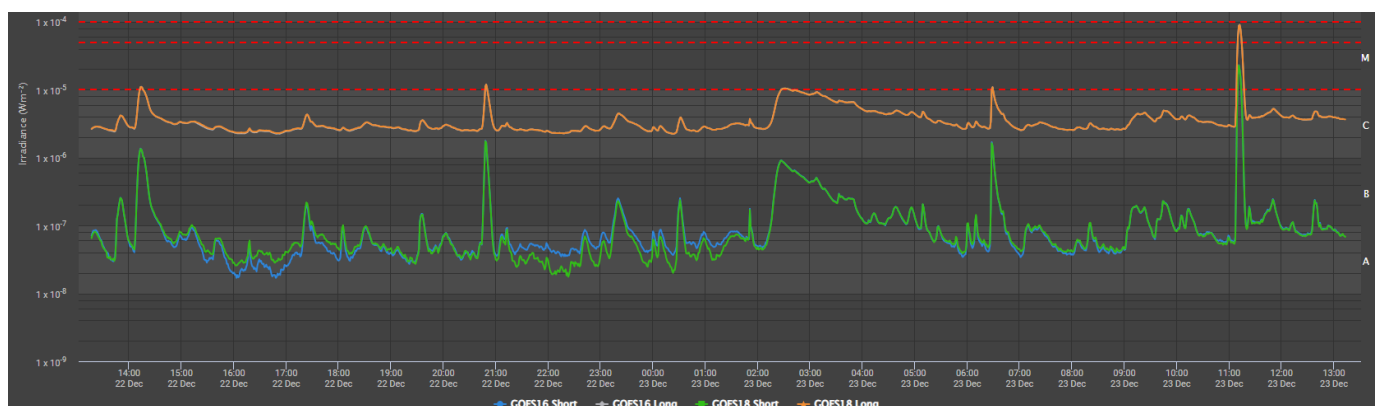
## Radio Blackouts - X-Ray Flares

Observed Solar flux continues to rise with currently eleven sunspot regions visible, two of which remain small and unnumbered for now. The southeast quadrant remains the focus of main solar activity, containing a cluster of the four largest regions, three of which (AR3928, AR3932 and AR3933) are moderately wide bipolar spot groups, showing some degree of magnetic complexity. AR3930 in the southwest will depart the visible disk into day 3 (25 Dec) but there is a likelihood of further regions rounding the eastern limb during the period, perhaps foremost among these a region in the northeast marked by increasing looping in SUIV imagery and GONG sounding data in recent days. This region possible early in the period with the potential for further smaller regions in the coming days given recurrence.

The assessment of any new regions notwithstanding, flare risk looks to remain heightened into the period and further M-class flares are considered likely, with a slight chance of X-class flares maintained throughout.

| X-Ray Flares | Level              | Past 24 Hours<br>(Yes/No) | Day 1<br>(00-24 UTC) | Day 2<br>(00-24 UTC) | Day 3<br>(00-24 UTC) | Day 4<br>(00-24 UTC) |
|--------------|--------------------|---------------------------|----------------------|----------------------|----------------------|----------------------|
| Probability  |                    |                           | (%)                  | (%)                  | (%)                  | (%)                  |
| Active       | R1-R2<br>(M Class) | Yes                       | 70                   | 70                   | 70                   | 70                   |
| Very Active  | R3-R5<br>(X Class) | No                        | 10                   | 10                   | 10                   | 10                   |

**Figure 2: Latest 24hr GOES16/18 X-Ray trace.**



Solar Radiation Storms (High Energy Protons)

The source of the currently observed enhancement in the near-Earth environment is uncertain, but a far-sided source seems most likely, perhaps from 19 December with possible further additions since. The chances of S1-scale or greater events are currently slightly raised as a result of the increased counts, however barring further additions, a relaxing back towards background values is forecast with time. This balanced by an increasing threat of near side enhancement, as the main sunspot regions currently located in the southeast, advance westwards.

| Radiation Storms                                                                                           | Level<br>(cm <sup>-2</sup> sr <sup>-1</sup> s <sup>-1</sup> ) | Past 24 Hours<br>(Yes/No) | Day 1<br>(00-24 UTC) | Day 2<br>(00-24 UTC) | Day 3<br>(00-24 UTC) | Day 4<br>(00-24 UTC) |
|------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------|---------------------------|----------------------|----------------------|----------------------|----------------------|
| Probability<br>(Exceedance)                                                                                |                                                               |                           | (%)                  | (%)                  | (%)                  | (%)                  |
| Active                                                                                                     | ≥ S1                                                          | No                        | 20                   | 20                   | 20                   | 20                   |
| Very Active                                                                                                | ≥ S3 *                                                        | No                        | 1                    | 1                    | 1                    | 1                    |
| * S3 ≥ 10 MeV ≥ 1000 pfu and/or 50 MeV ≥ 10pfu. (pfu = cm <sup>-2</sup> sr <sup>-1</sup> s <sup>-1</sup> ) |                                                               |                           |                      |                      |                      |                      |

High Energy Electrons (≥ 2MeV)

The current high energy electron flux is oscillating between background and moderate levels. This trend may accelerate at GEO given recently observed Elevated solar winds and periods of Unsettled geomagnetic activity, with the period as a whole carrying low confidence as a result of an uncertain CME picture and non-recurrent coronal hole influence.

MOSWOC REFM gives a reasonable guide, although does not represent either any potential CME activity nor non-persistent coronal holes, and as such the forecast carries low confidence as already mentioned. All considered, there is a gradually rising chance of 24-hour fluence reaching Active.

| GEO Electron Environment    | Level<br>(cm <sup>-2</sup> sr <sup>-1</sup><br>day <sup>-1</sup> ) | Past 24 Hours<br>(Yes/No) | Day 1<br>(00-24 UTC) | Day 2<br>(00-24 UTC) | Day 3<br>(00-24 UTC) | Day 4<br>(00-24 UTC) |
|-----------------------------|--------------------------------------------------------------------|---------------------------|----------------------|----------------------|----------------------|----------------------|
| Probability<br>(Exceedance) |                                                                    |                           | (%)                  | (%)                  | (%)                  | (%)                  |
| Active                      | ≥ 2 MeV<br>≥ 1×10 <sup>8</sup>                                     | No                        | 10                   | 20                   | 30                   | 40                   |
| Very Active                 | ≥ 2 MeV<br>≥ 1×10 <sup>9</sup>                                     | No                        | 1                    | 1                    | 1                    | 1                    |

Figure 3: Latest MOSWOC REFM model output.

